DOCUMENT RESUME

ED 149 167 CE 014 580

AUTHOR	Gilmore, Hal M.; And Others
TITLE	Implementing the Metric System in Agricultural Occupations. Metric Implementation Guide.
INSTITUTION	Illinois State Univ., Normal. Dept. of Mathematics.
SPONS AGENCY	Illinois State Office of Education, Springfield. Div. of Adult Vocational and Technical Education.
PUB DATE	[77]
NOTE	71p.; For related documents see CE 014 580-584
EDRS PRICE	MF-$0.83 HC-$3.50 Plus Postage.
DESCRIPTORS	*Agricultural Education; Instructional Materials; *Learning Activities; *Metric System; Teaching Guides; *Teaching Procedures; Teaching Techniques; Vocational Agriculture; Vocational Education

ABSTRACT

Addressed to the agricultural education teacher, this guide is intended to provide appropriate information, viewpoints, and attitudes regarding the metric system and to make suggestions regarding presentation of the material in the classroom. An introductory section on teaching suggestions emphasizes the need for a "think metric" approach made up of hands-on experience with the use of convenient referents (models for some of the commonly used units) but very little conversion between the metric system and the customary system. Major contents are in eight chapters: (1) The System, (2) Length, (3) Area, (4) Volume (Cubic Measure and Liter Measure), (5) Mass, (6) Volume-Mass, (7) Other Units (Temperature, Force, Energy-Work, Power, Pressure-Stress, and Torque), and (8) Miscellaneous Exercises. Each chapter includes explanatory material and a variety of suggested learning activities, some with directions addressed to the student. Some activities and exercises are of a general nature and some are related to specific occupational areas: agricultural production, agricultural supplies and services, agricultural mechanics, agricultural products, ornamental horticulture, and turf management. A bibliography and answers to the exercises are appended. (JT)

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METRIC IMPLEMENTATION GUIDE

IMPLEMENTING THE METRIC SYSTEM

IN

AGRICULTURAL OCCUPATIONS

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Illinois Office of Education
Department of Adult, Vocational and Technical Education
100 N. First Street
Springfield, Illinois 62777

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CE 014 580

F O R E W O R D

This book is intended to guide vocational-technical educators in the implementation of the metric system in the classroom. It is not an official or complete presentation and discussion of the system. Indeed, only a small portion of the metric system is appropriate for discussion in this document and for vocational-technical instruction. Books and documents are available which do present the official position for the use of the metric system in its entirety.

Through the years there have been many systems of measure labeled "the metric system," so it is important to understand which such system is meant when the term metric system is used. The U. S. Metric Conversion Act of 1975 declared that the system to be followed was the International System of Units as established by the General Conference of Weights and Measures in 1960, otherwise known as SI (Systeme Internationale). It is the SI to which professional, industrial and educational associations, government and educational agencies, and business enterprises are now converting.

In most countries of the world some segment of the society has used a metric system. It is likely, however, that at least some elements of that system do not conform to the SI. For example, in this country metric units have been used in the sciences and taught in science classes for years, but in large part they have been cgs (centimeter, gram, second) units, whereas the SI is a mks (meter, kilogram, second) system. This means that the dyne and other units in the cgs system are not accepted for use in the SI. The quintal

(100 kilograms), used in Europe and some in the U. S., is metric but is not acceptable for use in the SI. The micron (0.001 millimeter) is another example of a metric unit which is not an SI unit. The U. S. Government has formed a committee to guide in the conversion from the traditional system to the SI but it may be some time before certain practices and policies are agreed upon and adopted large-scale in this country.

In this book attention is focused primarily on SI. Secondarily, attention is given to other metric units and customary units, and their relationship to SI.

ACKNOWLEDGMENTS

One of the functions of the Mathematics Department of Illinois State University is to engage in projects which will improve the effectiveness of elementary, secondary and post-secondary, and teacher education programs. Another function is to serve the citizens of the State of Illinois. Both functions are combined in the preparation of this Metric Implementation Guide, for the guide should ease the transition to the metric system (SI) of measurement for students and those employed in agricultural occupations.

Measurement is a mathematical topic, but its use in agricultural occupations is best known by practitioners and educators in that field. The authors are deeply grateful to Rue Olson and Leonard Sigler for their assistance in gathering information for publication. Sincere thanks are extended to Dale Butz, Fred Fuess, Reg Henry, Gordon Ropp, Allan Utech, and Thomas Wiles for their helpful examination of drafts of this guide.

Gratitude is expressed to two IOE staff members: Gene Beenenga, for his assistance at every stage of the development, and Peggy Pool, for her logistic assistance. Special appreciation and gratitude go to Marilyn Parmantie for her tireless and efficient work in manuscript preparation.

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IMPLEMENTING THE METRIC SYSTEM IN AGRICULTURAL OCCUPATIONS

Developments incorporating the metric system into U. S. agriculture are taking place slowly. Some journals such as World Crops have been utilizing the metric system as the primary system for reporting measures for some time. On the other hand, many of the journals and magazines published in the United States rarely use the metric system. Some imported machinery is now designed and constructed using the metric system but most of the machinery produced in the United States is designed and built on the customary (English) system of measures. Although experimental agriculturalists have been using the metric system in their studies for years, the American farmer is not likely to feel the impact of the metric system until buying some new machinery.

American agriculture is a diversified enterprise. In contrast to the typical American who is likely to use only a few of the basic or derived metric units, those in agriculture will eventually need to understand and use several of the metric units--meter, kilogram, liter, pascal, degree Celsius, ampere, newton, and perhaps others.

As with the learning of any new system, a little confusion may occur when first learning the metric system. Its use will, however, simplify many situations in agriculture occupations. The impact of the changeover to the metric system will soon be felt throughout agricultural occupations. It is therefore appropriate and important to prepare all students for this development now.

Teaching Suggestions

The primary goal in teaching the metric system is--think metric. All of the activities and instructional procedures should be designed with that goal in mind. Teaching activities which are primarily lecture or teacher-focused, therefore, are inadvisable. Activities which emphasize measuring, estimating and thinking in the system are far more valuable. Filmstrips and overhead transparencies, commercially produced or otherwise, are of limited value. In fact, few of these filmstrips and transparency packets are without serious error and most are quite expensive. Worse, however, is that the use of these materials is deficient in the same way that lectures are deficient--the student is only a passive participant.

Hands-on Experience

The main focus of the instructional activities should be experiences in actually measuring, estimating and thinking metric. For example, after students become acquainted with the meter and its subunits (particularly decimeter, centimeter and millimeter) they might use a meter tape to answer such questions as the following:

How many meters long is the room?

The window pane is how many centimeters wide?

What are the centimeter dimensions of the face plate on the light switch?

Unsharpened pencil lead is how many millimeters thick?

For some initial measurement activities both the object to be measured and the unit to be used should be selected by the teacher. Measurements should be reported to the nearest whole unit.

After some time has been spent with these measurement activities, activities in estimating lengths of various objects should be provided. The

objects to be measured and the units to be used should be varied. The emphasis should be "estimate, then check by measuring." Care should be taken to avoid precise measurements in checking. The goal is not great skill in estimating and measuring; the goal is think metric—internalize the units.

Convenient Referents

Students should look for convenient models for some of the commonly used units. It might be, for example, that the width of the nail on their little finger is about 1 cm, the distance across the back of their hand is 1 dm, or the top of their hipbone is about 1 m above floor level. Objects commonly carried in pocket or purse may provide convenient models.

The purpose of such an approach is to promote thinking metric on the part of students who have grown up learning to think in and to use the English system and who must now, in a short period of time, change and begin to think metric. Precise measurements and accurate estimates are not especially important. What is important is that the students quickly build in a set of referents which will thus enable them to make judgments about measurements of other objects as well as to internalize the metric system. This approach should be applied to the teaching of area, volume, and mass as well.

Little Conversion

Conversions between the metric system and the customary system should be avoided while learning the metric system. Conversions between systems can be made, when necessary, by simply consulting a table of equivalents readily available and doing the necessary multiplication or division. This is something which needs little instruction. It is appropriate, however, to make a few rough basic comparisons such as between the meter and the yard, the liter and the quart, and so on.

Conversions within the metric system, on the other hand, are quite a different matter. Converting from one metric unit to another is easily done by simply multiplying or dividing by a power of 10; a very simple task compared to converting in the customary system. Perhaps because it is so easy there is a tendency for teachers to overemphasize this activity. Some practice with conversions in the metric system is appropriate but practicing mechanical shortcuts is of questionable value. Instead, it seems more appropriate and beneficial to reason from the basic relationships between the units. Consider the following:

1. 750 grams = _____ kilogram(s)

   The reasoning could be:

   We have 750 grams and it takes 1000 grams to make a kilogram, so we have only 0.750 kilogram.

2. How many milliliters does a 3-liter container hold?

   The reasoning might be:

   The container holds 3 liters, and since 1 liter is 1000 milliliters the container holds 3000 milliliters.

Use of This Guide

This guide is addressed to the teacher. Its aim is to provide appropriate information, viewpoints, and attitudes regarding the metric system and to make suggestions regarding the presentation of the material in the classroom. A variety of activities is given and directions for some of these are addressed to the student. Nevertheless, it is not intended to be a workbook for students, nor is it intended that the activities given are sufficient or comprehensive. The attempt has been made to provide examples of suitable activities designed to help the students think metric.

Several types of activities are suggested in each section. Each of these types makes a unique contribution to the learning process. It is appropriate, then, that some of each type should be provided for the student as each section is developed.

I. Measure

e.g., p. 13, item 1

II. Estimate and Measure

e.g., p. 27, item 2

III. Reasonable ("ball park") Estimates

The diameter of an aspirin tablet is _____.

(a) 3 m (b) 1 cm (c) 15 mm

IV. Metric Conversion Drill

1450 g = _____ kg

V. Applications

This guide is addressed to agricultural occupational programs including Agricultural Production, Agricultural Supplies and Services, Agricultural Mechanics, Agricultural Products, Ornamental Horticulture, and Turf Management.

Some of the activities and exercises included are of a general nature and some are related to specific occupations. It is intended that the teacher will select from the items suggested those which are appropriate to the group of students involved and it is expected that those suggested will stimulate the creation of additional or more appropriate items by the teacher.

It must be emphasized again that the actual measurements of some of the objects given are not important. What is important is that the students have the opportunity to actively estimate and measure many objects with which they have frequent contact; that they be encouraged to "think metric."

The System

The metric system had its beginning in the latter part of the 18th century when a group of French scientists, commissioned by their government, developed a system of measurement units. The system was officially adopted by the French government in 1795, and in 1840 its use was made mandatory by the government. Over the years most of the countries of the world, including the United States, have adopted it. In 1866 the U. S. Congress passed an act making it legal but not mandatory to use the metric system in the United States. The Eleventh General Conference on Weights and Measures, meeting in 1960, adopted the International System of Units (SI)—the universally recognized metric system today. In December, 1975, HR 8674 was signed into law by President Ford, a bill that provides for the establishment of a 17-member metric board that will coordinate the voluntary conversion to the SI in the U. S.

The SI is a modernized metric system of measurement with features which make it superior to the U. S. customary system and to other metric systems. One feature is that the base of the system is absolute; that is, force is not defined by action of gravity. An absolute system makes for simplicity of calculation. In SI units, a force of one newton gives a mass of one kilogram an acceleration of one meter per second per second. By contrast, in the European system, a force of one kilogram-force accelerates a mass of one kilogram 9.806 650 meters per second per second, and in the U. S. customary system, one pound-force accelerates a mass of one slug 32.174 feet per second per second. Another feature is coherence. In a coherent system any derived unit is related to any other, or to the base units, without the use of conversion factors. A third feature is that only one unit is used for each physical quantity. By

contrast, the customary system has nine commonly used units for area, 25 units for energy, and 26 units for length.

The SI consists of seven base units, two supplementary units, and derived units, some of which have been given special names.

Base Units

Unit	Quantity	SI Symbol
meter	length	m
kilogram	mass	kg
kelvin	temperature	K
ampere	electric current	A
mole	molecular substance	mol
second	time	s
candela	light intensity	cd

The derived units are determined by multiplying or dividing base units, without using numerical factors other than one. Some of these are shown below. For a more complete listing of these units see Appendix A or a source from Appendix C.

Some Derived Units Without Special Names

Unit	Quantity	Formula
square meter	area	m^2
cubic meter	volume	m^3
meter per second	linear velocity	m/s
kilogram per cubic meter	density	kg/m^3

Some Derived Units With Special Names

Unit	Quantity	SI Symbol	Formula
newton	force	N	$m \cdot kg \cdot s^{-2}$
pascal	pressure	Pa	N/m^2
watt	power	W	J/s
joule	energy	J	N·m
coulomb	electric charge	C	A·s
volt	electric potential	V	W/A
hertz	frequency	Hz	1/s or s^{-1}
ohm	electric resistance	Ω	V/A
farad	electric capacitance	F	C/V

Multiples and submultiples of these units are expressed by means of certain prefixes.* Some of the prefixes are:

Prefix	Meaning	SI Symbol
mega	1 000 000	M
kilo	1 000	k
hecto	100	h
deka	10	da
deci	0.1	d
centi	0.01	c
milli	0.001	m
micro	0.000 001	μ

*For a more complete listing of the prefixes, see Appendix A.

The prefixes have decimal meanings, i.e., each is a power of ten, and conversions among the units is facilitated by a knowledge of our numeration system.

Examples

1 hectogram	= 100 grams	(1 hg = 100 g)
1 centimeter	= 0.01 meter	(1 cm = 0.01 m)
1000 grams	= 1 kilogram	(1000 g = 1 kg)
1 meter	= 10 decimeters	(1 m = 10 dm)
1 deciliter	= 0.1 liter	(1 dL = 0.1 L)*

Not all the prefixes will be used in actual practice. Note that the SI symbol for a unit is used for both the singular and plural forms. Other established conventions for spelling, usage, etc., include:

1. Symbols for unit names are written in lower case unless they are derived from proper names. Most SI symbols for unit names are single letters (for some exceptions see Appendix A).

   RIGHT: Contents 454 g
   WRONG: Contents 454 GM

2. Periods are not used after the symbols or prefixes unless a sentence ends with such.

   RIGHT: The pencil is 16 cm long.
   WRONG: The pencil is 16 cm. long.

3. A zero digit is used in the units place when naming a number less than 1.

   RIGHT: The distance to the next road is 0.8 km.
   WRONG: The distance to the next road is .8 km.

---

*The symbol for liter as prescribed in the SI is "ℓ". In December, 1976, however, the National Bureau of Standards stated that the capital letter "L" will be used instead in the U. S. This symbol has several advantages over the "ℓ" and has been urged for adoption in the SI.

4. Numerals containing more than four digits should be separated into groups of three digits in order to facilitate reading. No commas should be used in the spaces between groups of digits.

   RIGHT: The distance from the earth to the moon is about 385 000 km.
   WRONG: The distance from the earth to the moon is about 385,000 km.

5. Prefixes are not to be used without a unit.

   RIGHT: The weight lifted was 186 kilograms.
   WRONG: The weight lifted was 186 kilos.

Additional information and discussion of the metric system may be found in a number of current sources (Appendix C).

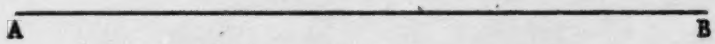
Length

In agricultural occupations the metric system has been little used in measuring length. This means that as the country shifts to the metric system there will be some impact on personnel in the agricultural occupations. Perhaps the impact will be felt initially in agricultural mechanics as machinery is produced with metric components. Other practices in the measurement of length may be slow to change. At the present time little hard conversion has taken place.

In the metric system (SI) the basic unit of length is the meter--probably the most familiar of the metric units. The meter is a little longer than the yard; slightly less than a 40-inch row width. Other metric units of length which are frequently used are:

kilometer--about 0.6 mile (or about 200 rods) — 1 km = 1000 m

decimeter--the length of segment AB — 1 dm = 0.1 m



centimeter--the length of segment CD — 1 cm = 0.01 m

millimeter--the length of the segment to the right — 1 mm = 0.001 m

Suggested Activities*

1. Find several objects which have approximately the measurements in the chart below. Try to find things which you can easily remember or that you are frequently near. Include body measurements such as palm width, length of a finger, distance from hip to floor, etc.

1 m	1 dm	1 cm	1 mm

*The activities suggested in this book are meant to include several areas in the agricultural occupations. The teacher may select from these activities those most appropriate to the subject and students being taught.

2. Use the objects listed below and others from your school or home to practice linear measurement. The main objective is to develop a better "feel" for metric units of length, and therefore rough estimates and measures are adequate. Some objects you are near frequently; the measures of these (fence post height, for example) you will want to remember. More than one dimension of some objects may be estimated. Check your estimates by measuring.

Object	Estimated Length	Measured Length
Shrub		
Pane of glass		
Concrete block		
Fence post		
Tomato plant		
Your height		
Checkbook		
Floor tile		
Wagon bed		
Mower setting		
Water supply pipe		
Greenhouse		
_____		
_____		
_____		

The purpose in all these activities is to help foster "thinking metric"! Accuracy in estimating is not crucial. Discourage students from measuring too precisely here.

3. Draw a line segment that has length

(a) 1 dm (b) 5 cm (c) 3 mm (d) 15 cm (e) 20 cm

Check by measuring. Try again with some other lengths until you are satisfied with your estimating skill.

A feel for metric units is important. Practice with estimating helps to think metric. Exercises such as the following also help. They will be of little

value, however, if students do them by conversion. Instead, they should be done by just considering what is a reasonable answer. The measures given in exercises 4 and 5 and in similar exercises later in the unit are not important. Students may not know these measures nor do they need to in order to answer the questions. They should be able to rule out the inappropriate units or measures just by a general familiarity with the objects involved.

4. Supply the appropriate unit to make the sentence reasonable. Choose from mm, cm, dm, m, and km.

   a. The length of the dairy barn is 40 _____.

   b. Farmers can check for brown stem rot in their soybeans by cutting open the stem 15 _____ above ground level. If stem rot is there, the center of the stem will have a chocolate brown color. A healthy stem has a white center.

   c. A windbreak of Norway spruce 8 _____ tall can reduce the wind velocity from 50-96 percent.

   d. The hornworm, a tobacco pest in the U. S., grows to 75-100 _____ in length and can eat large quantities of foliage.

   e. For "heeling-in" bare-root trees a trench 2.5-3 _____ deep may be used.

   f. The esophagus of a horse is 125-150 _____ long.

   g. A soybean demonstration plot on a farm in Paxton included two soybean varieties planted in row widths of 95 _____, 75 _____, 47.5 _____ and 25 _____.

5. Choose the best answer from those provided.

   a. To get side-shoot production on a young apple tree, during the first season cut back the young tree to _____.

      (1) 80 dm (2) 80 mm (3) 80 cm

b. A steel fence post is _____ long.

(1) 15 dm (2) 40 cm (3) 200 mm

c. A good windbreak 12 meters high gives sufficient protection to buildings and lots to a distance of about _____.

(1) 120 dm (2) 96 km (3) 96 m

d. The hammer handle is _____ long.

(1) 0.5 m (2) 0.5 dm (3) 30 cm

Converting between metric measures is a needed skill. It is much easier than in the customary system (yards to rods, etc.), so there is some danger of overemphasizing this activity or of emphasizing mechanical procedures. Conversions among mm, cm, dm, m and km are all that are required. Knowledge of a few basic relations of a decimal nature is sufficient for this.

10 mm = 1 cm	10 dm = 1 m	1000 mm = 1 m
10 cm = 1 dm	1000 m = 1 km	100 cm = 1 m

For example, since 1 dm = 10 cm

8.6 dm = (8.6 x 10) cm = 86 cm.

Likewise, since 1 dm = 100 mm

8.6 dm = (8.6 x 100) mm = 860 mm.

6. Complete the following:

a. _____ mm = 56 dm

b. 56 dm = _____ m

c. _____ m = 3.2 km

d. 28 cm = _____ mm

e. 28 cm = _____ m

f. 8000 m = _____ km

g. 6 m 3 dm 5 cm = _____ m = _____ cm

h. 5 cm 8 mm = _____ cm = _____ m

For "fun":

i. _____ in. = 3 yd. 2 ft. 7 in.

j. 2 yd. 1 ft. 5 in. = _____ yd. = _____ in.

7. A field 300 m x 400 m is to be enclosed with 3 strands of barbed wire fencing. How many meters of wire are needed? If each roll of wire is 400 m long, how many rolls will be needed?
8. If corn is planted in rows 75 cm apart, how many rows would be in a field 300 m wide?
9. If beans are planted 3 cm apart in the row, how many beans would be planted in a 240 m row?

The preceding activities should help gain familiarity with measurements of length in the metric system but agriculture will be using a dual system for some time. Consequently, some conversions between the customary and metric systems will be necessary. Most such conversions will not be so exacting as to demand more knowledge than the following: ("≐" means "is approximately equal to")

1 inch ≐ 2.5 cm

1 ft. ≐ 30 cm

1 meter ≐ 39 in.

0.4 in. ≐ 1 cm

1 mile ≐ $\frac{8}{5}$ km = 1.6 km

1 km ≐ $\frac{5}{8}$ mile ≐ 0.6 mile

1 rod ≐ 5 m

10. Complete the following:

a. 30 in. ≐ _____ cm

b. 200 cm ≐ _____ in.

c. 10 m ≐ _____ in.

d. 40 km ≐ _____ miles

e. _____ km ≐ 50 miles

f. 20 rods ≐ _____ m

g. 500 ft. ≐ _____ cm = _____ km

h. 88 km/h ≐ _____ mph (i.e., 88 km ≐ _____ miles)

Area

Metric units of area will be used in one form or another quite frequently in agricultural occupations. The size of fields, farms, and bodies of water will be given in hectares and the size of counties and cities may be stated in square kilometers. The areas of smaller regions will be given in terms of square meters and for very small regions the square centimeter will be used.

It is likely that legal records of land will remain unchanged for some time because they have a small part in everyday business. Such changes will probably take place only when deeds are transferred.

Suggested Activities

A unit of area convenient in many instances is the square centimeter: . "Square centimeter" is expressed with the symbol cm^2.

1. Make a model of a square centimeter from paper.
2. Use your model to estimate the area of these regions.

Figure 1

Figure 2

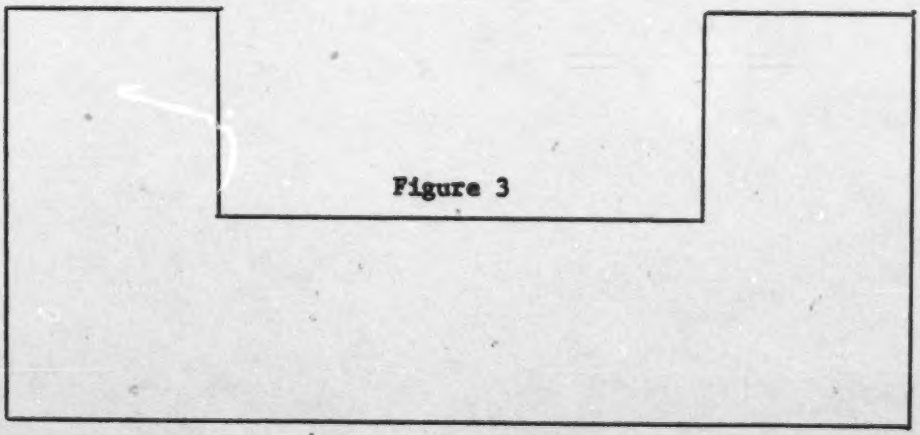


Figure 3

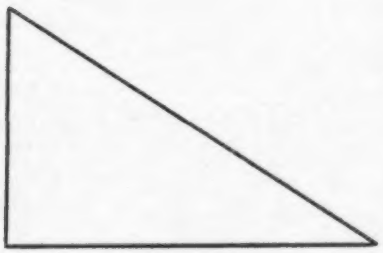


Figure 4

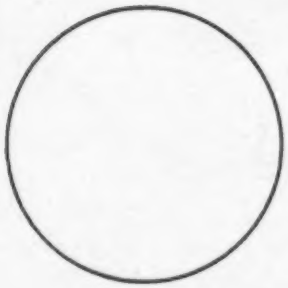


Figure 5

Region	Estimated Area
1	_____
2	_____
3	_____
4	_____
5	_____

The area of a rectangular region is, of course, computed by the formula $A = lw$. For example, a rectangle 2 m by 3 m has an area of 6 square meters (6 m^2); a rectangle 2 cm by 3 cm has an area of 6 cm^2; a large room 8 m by 10.5 m has an area of 84 m^2. Formulas for the area of a triangle and circle are $A = \frac{1}{2}bh$ and $A = \pi r^2$.

3. Check your estimates in number 2 by using your ruler to measure any segments needed to calculate the area.

Region	Calculated Area
1	_____
2	_____
3	_____
4	_____
5	_____

Another convenient unit of area is the square decimeter (dm^2).

4. Make a model of this square unit from heavy paper. Use your model as an aid to estimate the area of several objects. Check your estimate by measuring and calculating. Some objects are suggested; include others from your classroom, home, or place of work.

Object	Estimated Area	Calculated Area
File cabinet		
Greenhouse bench		
Table top		
Tool cabinet		
Wagon bed		
Lawn		
Book cover		
Window pane		
Floor tile		
Door		

5. A square meter is a rather large unit of area. What objects can you find in your classroom that have an area of approximately:

a. 2 m^2 _____ _____

b. 4 m^2 _____ _____

c. 0.5 m^2 _____ _____

6. Choose the best answer from those provided.

a. The area of McLean County, Illinois, is about _____.

(1) 3072 m^2 (2) 3072 km^2 (3) 3072 cm^2

b. The floor of a two-car garage is _____ in area.

(1) 10 000 m^2 (2) 0.2 m^2 (3) 48 m^2

c. The area of the postage stamp is about _____.

(1) 3 cm^2 (2) 1.5 dm^2 (3) 5 m^2

d. The grain truck was covered with a canvas tarp having an area of about _____.

(1) 22 m^2 (2) 5 000 mm^2 (3) 2 km^2

7. Calculate the area of each of these rectangular regions:

a. 4 m x 5 m

b. 6 cm x 8 cm

c. 3.6 m x 8 m

d. 27.5 m x 7.6 m

e. 350 m x 500 m

f. 285 m x 312 m

8. Using the given dimensions for a rectangular region find the area in cm^2.

a. 4 m x 18.5 cm

b. 2 m x 3 m

c. 2.5 m x 4.2 cm

d. 22 cm x 28 cm

Find the area in m^2.

e. 420 cm x 5 m

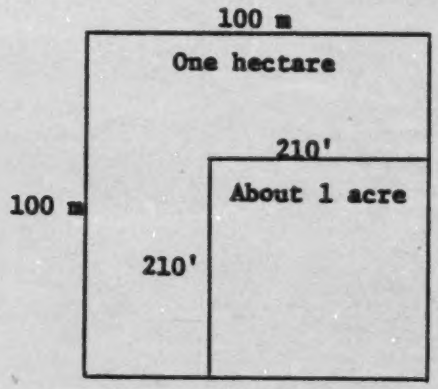
f. 118 cm x 25 cm

g. 65 cm x 6.25 m

h. 0.5 m x 120 m

Sometimes a larger unit of area is convenient. The SI permits the use of hectare (ha) as a unit for measuring large land or water areas. 1 hectare = 10 000 m^2, so a plot 200 m by 300 m has an area of 6 ha. A medium sized farm might have an area of 80 ha.

Over the years some people have estimated an acre of land by "stepping off" a square 70 paces by 70 paces. To approximate one hectare of land, one could step off a square 100 paces on a side making sure to take a long step.



9. A football field is about 49 m by 100 m (including one end zone). It has an area of about _____ m^2. Two football fields have an area of about _____ m^2. One hectare is 10 000 m^2, so two football fields have a combined area of approximately 1 hectare.

   Find the area in hectares.

   a. 60 m x 75 m
   b. 150 000 m^2
   c. 100 m x 100 m
   d. 20 m x 1 km

A square 100 cm on each side is the same size as a square 1 m on each side. Such a square would contain 100 rows of 100 cm^2 each. Consequently 1 m^2 = 10 000 cm^2.

10. Complete the following.

a. $3\ m^2 = \_\_\_\_\_\ cm^2$

b. $\_\_\_\_\_\ m^2 = 5000\ cm^2$

c. $5\ dm^2 = \_\_\_\_\_\ cm^2$

d. $250\ cm^2 = \_\_\_\_\_\ dm^2$

e. $40\ 000\ cm^2 = \_\_\_\_\_\ m^2$

f. $5\ cm^2 = \_\_\_\_\_\ mm^2$

11. Supply the appropriate unit to make the sentence reasonable. Choose from cm^2, dm^2, m^2, km^2 and ha.

a. The area of a small town is about 2.56 _____.

b. This sheet of paper has an area of about 616 _____.

c. The floor of a corn bin has an area of about 38.5 _____.

d. The eye of a rib eye steak is about 75 _____ in area.

e. The dry fertilizer blending equipment was housed in a 1500 _____ plant located just east of Goodfield.

f. On a field tour of a bean plot a researcher displayed a plant which bore 263 pods and which averaged 2.5 beans per pod. The plant was selected from the middle of a row in the plot which was planted at 375 000 plants per _____.

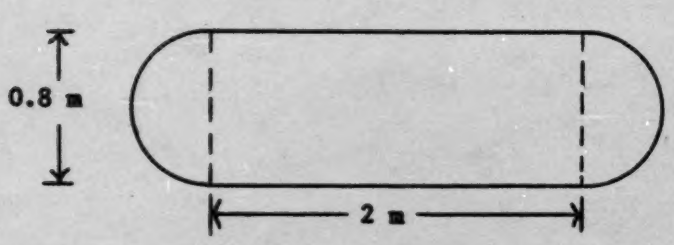
g. A rancher has 1000 head of sheep grazing across 6000 _____ of land just north of Roswell, New Mexico.

h. A certain hybrid of corn produced three ears on most stalks and had a yield of 10 560 kilograms per _____.

12. Galvanized steel roofing is available in panels 3.5 m^2 in size (approximately 0.8 m by 4.3 m). This is equivalent to _____ dm^2.

13. A table top 120 cm by 300 cm has an area of 36 000 cm^2 or _____ m^2.

14. A steel watering tank with round ends is 0.8 meter tall with base dimensions as shown. To find the liter capacity of the tank we may multiply the number of square decimeters in the base by the number of decimeters in the height. The area of the base is $[\pi \cdot (0.4)^2 + 2 \cdot (0.8)]\ m^2 \doteq 2.1\ m^2 =$ _____ dm^2.



15. Each of the 5 shelves in a metal storage cabinet is 6 dm wide and 9 dm long. The total storage area of these shelves is _____ dm^2 or _____ m^2.

Conversions between the metric and English systems involving area need not be stressed but some relationships will no doubt be used occasionally. It just happens that relationships exist between hectares and acres similar to those between the inch and centimeter.

1 hectare $\doteq$ 2.5 acres	1 inch $\doteq$ 2.5 centimeters
1 acre $\doteq$ 0.4 hectare	1 centimeter $\doteq$ 0.4 inch

16. Complete the following.

a. 80 acres $\doteq$ _____ ha

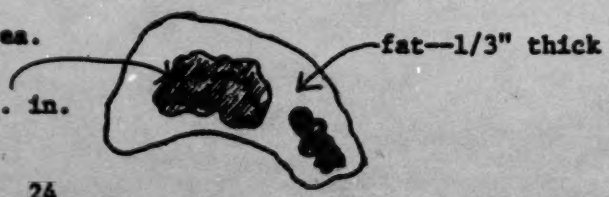
b. 4 ha $\doteq$ _____ acres

c. 30 ha $\doteq$ _____ acres

d. 500 acres $\doteq$ _____ ha

e. 1 sq. mile $\doteq$ _____ acres $\doteq$ _____ ha

17. A nice rib eye steak is described in customary terms as shown. Since 1 inch $\doteq$ 2.5 cm, then 1 sq. inch $\doteq$ _____ cm^2. The eye of this steak is therefore about _____ cm^2 in area.



18. A desirable plant population for corn is 26 000 plants per acre. What should be a similar population per hectare?

Volume

In raising grain, in feeding livestock or in working with farm machinery the concept of volume arises frequently. Corn, soybeans, and the fruits and vegetables from truck gardens, for example, are frequently sold by the bushel. Water tanks for livestock, milk containers, fuel tanks, and buckets for numerous uses have their volume expressed in gallons or quarts. The displacement of engines for cars, trucks and farm machinery is measured in cubic inches. In the kitchen teaspoons, tablespoons, cups, pints, quarts, and ounces are used. For dry measures ounces, quarts, gallons, pecks, and bushels are used. In the metric system, however, there will be only two ways for expressing volume--in cubic units and in liters.

Cubic Measure

The cubic meter, cubic decimeter and cubic centimeter will be the commonly used cubic units. Engine displacement and medicine dosages may be given in cubic centimeters. The abbreviation cc. is commonly used in such cases but correct SI form dictates that the symbol cm^3 be used. The cubic meter (m^3) may be used to express the capacity of grain bins, silos, grain beds on trucks or wagons or the volume of rooms or buildings. The cubic decimeter (dm^3) may not be used often but it plays an important role in relationships with other metric units which will be discussed later.

The volume of a rectangular solid is given by the formula $V = lwh$. The volume of a cylinder is $V = \pi r^2 h$. In these cases and in others where the volume can be computed by formula, cubic units will be used to express the volume. In many other cases the liter (discussed later) will be used.

Suggested Activities

1. a. Make a model of a cubic centimeter and cubic decimeter out of heavy paper. A suggested diagram is given in Appendix B. (Metal or wood is suitable, also.)

   b. Make a model of a cubic meter using meter sticks or similar material for edges.

   c. Challenge. Make a model of a cubic millimeter.

2. Estimate the volume of several objects in the room by thinking of cubic units—m^3, dm^3, or cm^3. Check your estimates by measuring with the cubic unit or a tape. Some objects are suggested; include others from your room, home, or place of work.

Object	Estimated Volume	Calculated Volume
Tool box		
Cut flower cooler		
Chalkboard eraser		
File cabinet		
Teacher's desk		
Grain wagon		
Truck battery		
Shotgun shell box		
Electrical outlet box		
Electric heater		
Dehumidifier		
Upright freezer		
_____		
_____		
_____		

3. Supply the appropriate unit to make the sentence reasonable. Choose from cm^3, dm^3 and m^3.

   a. The volume of a car battery is about 9 _____.

   b. An electrical switch box measures approximately 360 _____.

   c. The capacity of a car top carrier is almost 1 _____.

   d. A box of fifty 22-caliber rifle shells would have a volume of about 25 _____.

e. A milk bucket would hold about 20 _____ of milk.

f. A livestock watering tank would have a volume of 2 _____.

4. Remembering that it would take 1000 cm^3 blocks to occupy the space of one dm^3 and 1000 dm^3 blocks to fill one m^3, complete the following blanks to make true sentences.

a. 2 m^3 = _____ dm^3

b. 500 cm^3 = _____ dm^3

c. 4000 cm^3 = _____ m^3

d. 4000 dm^3 = _____ m^3

e. 0.42 dm^3 = _____ cm^3

f. 1.491 m^3 = _____ dm^3

g. 0.1024 dm^3 = _____ cm^3

h. 186 321 cm^3 = _____ m^3

i. 144 dm^3 = _____ cm^3

j. 144 dm^3 = _____ m^3

5. An antibiotic sulfa combination for mastitis comes in a box of six 28 cm^3 syringes. This is _____ dm^3 of medicine.

6. A stock tank heater will keep a cubic meter of water drinkable (11 °C or well water temperature). Would it have the ability to do the same for an 880 dm^3 round-end watering tank? _____YES _____NO

7. A trailer with a capacity of 283 160 cm^3 would hold _____ m^3 of fertilizer.

8. An Owens Fifth Wheel trailer has dimensions 1 m x 5 m x 2.3 m. What is the volume in m^3?

9. A railroad box car is 15.4 m by 2.8 m by 3.2 m. Find the capacity of the car in m^3.

10. A 1 dm^3 box of Hoof Magic dressing can provide 200 applications of _____ cm^3 each.

11. A stack of 50 m^3 of loose hay might last 10 days if the livestock eat _____ dm^3 of hay daily.

Liter Measure

The liter is not one of the basic SI units but it is a convenient unit and is used frequently enough that it has been accepted by the SI. The liter is just a little larger than a quart and will probably be used for small to moderately sized amounts. For large amounts it seems likely that the cubic meter will be the appropriate unit. So there are two alternatives for describing measures of volume or capacity--cubic measure and liter measure.

There is no set rule stipulating which of the two measures should be used in a given situation. It seems to be simply a matter of custom and convenience. For example, we may have milk containers of 1 liter, 2 liters, or 4 liters. Galvanized, stainless steel, or other pails may be sized in liters. A 10-liter pail would be a convenient size for many purposes. The present 5-gallon bucket may ultimately be replaced by the 20-liter pail. Tank wagons or insecticide spray tanks and fuel tanks may be sized in liters or in cubic meters.

Smaller amounts will be measured in milliliters in some instances and in cubic centimeters in others. For example, vaccines or antibiotics may be prescribed in cubic centimeters. Other medicine dosages may be described in milliliters.

One of the nice features of the metric system is the ease with which one may change from one unit of measure to another. This pertains to the interchange between cubic measure and liter measure as well. A liter container holds exactly the same amount as a cube one decimeter (10 cm) on each edge; that is, $1\ L = 1\ dm^3$. Consequently, a 10-liter pail has a volume of 10 cubic decimeters; a 2-liter milk carton has a volume of two cubic decimeters, and a 1000-liter tank has a volume of 1 cubic meter.

Since a cube 10 centimeters on each edge contains 1000 cubic centimeters, each of these cubes is 0.001 of a cubic decimeter and hence is 0.001 of a liter.

That is, one cubic centimeter equals one milliliter. In some areas, principally in medicine, the cubic centimeter and the milliliter are constantly used interchangeably. A dose of 20 cubic centimeters is equal to 20 milliliters.

There are some useful approximations between customary household measures of volume and metric measures of volume. One teaspoon is approximately equal to five milliliters, one tablespoon is approximately equal to fifteen milliliters, and the customary measuring cup used in cooking holds about 240 milliliters. There has been a great deal of discussion to the effect that a "metric cup" is the equivalent of 250 milliliters. Actually, there is no valid reason why the term metric cup should be used at all. It is true that for cooking purposes and other uses we will find it convenient to have a container with a capacity of 250 milliliters, but there is no reason to distinguish this container by referring to it as a metric cup.

As with other metric units, it is important to develop a feel for the metric units of liter and milliliter. Classroom activities such as the following may help with this.

Suggested Activities

1. Estimate the capacity of each of these. Check your estimates by using water and a graduated cylinder to measure capacities of small containers. Use shelled corn, oats, or vermiculite to check estimates of larger containers. Select some other containers familiar to you and learn their capacity.

Object	Estimated Size	Measured Size
Milk strainer		
Thimble		
Soup spoon		
Dinner glass		
Flower pot		
Box for hand tools		
Pop can		
No. 2 scoop shovel		
Battery hydrometer		
Gas line antifreeze can		
Grain basket		
_____		
_____		
_____		

2. Supply the correct unit to make each sentence reasonable. Choose from liter (L) or milliliter (mL).

   a. Mary poured 100 _____ of syrup on her hotcakes.

   b. Asbestos fibered roof coating is available in either the 4 _____ or the 20 _____ can.

   c. A syringe containing 30 _____ of antibiotic sulfa injection for mastitis infection is available from your dealer.

   d. A large drum of multipurpose grease has a volume of approximately 10 _____.

   e. The Jersey milk cow averaged 7.5 _____ of milk per day.

   f. Approximately 3250 _____ of diesel fuel is needed to raise 40 ha of minimum tillage corn with no plowing.

3. Choose the best answer from those provided.

a. Four-year-old, bare-root spruce trees may be planted and grown for two years in _____ cans before transplanting.

(1) 4 L (2) 100 mL (3) 0.5 dm^3

b. A gasoline supply can for a riding mower has a capacity of about _____.

(1) 80 L (2) 800 mL (3) 8 L

c. An ink refill tube for a fountain pen contains _____ of ink.

(1) 22 L (2) 2 mL (3) 20 mL

d. The extra large picnic ice chest has a capacity of _____.

(1) 5 L (2) 51 L (3) 510 L

The liter and milliliter are probably the only two liter measures that will be used in practice. Conversions between the two are done simply by remembering that

1 L = 1000 mL

1 mL = 0.001 L

For example, 258 mL = 0.258 L.

4. Complete the following.

a. 1 liter = _____ mL

b. 2000 mL = _____ L

c. 30 000 mL = _____ L

d. 0.25 L = _____ mL

e. 0.001 L = _____ mL

f. A 10-liter bucket holds _____ mL.

g. A 22 mL dose of medicine is _____ L.

h. A liter of gunpowder will fill 100 shotgun shells at a charge of _____ mL each.

5. A new 12 volt tractor battery comes with 2.4 liters of battery acid. Each of its six cells would need _____ mL.

6. A one-half liter bottle of medication for livestock drinking water will medicate 40 liters of water. One would use _____ mL to medicate a 400 mL water bowl.

7. A 500-liter auxiliary fuel tank for a truck would hold _____ mL of gasoline.

8. A truck which uses 5 mL of oil per kilometer will be able to travel _____ kilometers before it uses a liter of oil.

9. If a fish tank heater costs 1¢ to heat a 40-liter aquarium per day, it might be expected to heat _____ mL of water for a half cent.

10. Make the following conversions between cubic units and liter measures.

    a. 18 cm^3 = _____ mL

    b. 5 dm^3 = _____ L

    c. _____ cm^3 = 250 mL

    d. 18 L = _____ dm^3

    e. 1.5 L = _____ m^3

    f. 0.3 dm^3 = _____ mL

    g. A box 2 cm by 3.5 cm by 10 cm has a volume = _____ = _____ mL.

11. For mosquito larvae control, No. 2 grade fuel oil may be applied to surface water at the rate of _____ per hectare of water.

    (a) 20 to 50 mL (b) 1 to 4 L (c) 20 to 50 L

12. If you poured a liter of oil into a quart can would it overflow?

Mass

The gram and kilogram are the two primary quantities of mass which will be used in agriculture, along with some use of the metric ton and the milligram. The kilogram will be used in discussing crop yield, seeding rates, cattle size, and fertilizer application. On the other hand, the gram will be used when buying such things as flower and vegetable seeds, rice, beans and canned goods; the kilogram will be used when buying meats and other larger quantities. The gram may be used as an alternative to volume measure for cooking. Large grain shipments are presently described in metric tons; some medicine ingredients are given in milligrams.

The terms mass and weight and their use have recently had considerable discussion. Mass is a quantity with an SI base unit and force is a quantity with an SI derived unit, but the term weight does not appear in SI. In science and engineering, however, the term weight has been used but a distinction between mass and weight has been carefully maintained. Currently, practices are being implemented (see Guidelines for Writers of SI Metric Standards, Appendix C), which will mean that the term weight will no longer be used in science and other technical fields. Instead, the term force of gravity will be used. In general everyday use, including the agricultural occupations, no harm will occur by using the terms weight and mass synonymously.

Some abbreviations for metric units are in current use which do not conform to SI style practices. It is common to see the symbol gm, the abbreviation Gm., and other expressions for gram. The symbol g, however, is the proper SI symbol for gram. "Kilos" is sometimes used in reference to the mass of an object, particularly in athletic weight lifting events. This incorrect and misleading usage should be avoided.

The quintal is a unit which has been used in Europe and has been suggested for use in the United States, but this unit is not acceptable for use in SI. For the sake of general information the Ag teacher could mention that the quintal is equal to 100 kilograms, but further discussion is inadvisable.

The kilogram is about 2.2 pounds--a little heavier than a box of American processed cheese. The gram, which is only one-thousandth of a kilogram, is about the mass of a hog ring. A metric ton = 1000 kilograms and 1 milligram = 0.001 gram.

Suggested Activities

1. Supply the appropriate unit to make the sentence reasonable. Choose from metric ton, kilogram (kg), gram (g), and milligram (mg).
   a. A pail of milk has a mass of 14 _____.
   b. A golf tee has a mass of 1 _____.
   c. The mass of a bottle of Tylan Plus Vitamins is 250 _____.
   d. A piece of paper this size □ has a mass of 1 _____.
   e. A feeder steer ready for market has a mass of 0.5 _____.
   f. A 100 mL bottle of Tylan 50 Injection contains 100 _____ of Tylosin.
   g. A water tank (for cattle) full of water has a mass of 1.6 _____.
   h. It was estimated that average corn yield in Woodford County, Illinois, in 1976 would be about 7250 _____ per hectare.
   i. The U. S. Agriculture Department reported that officials scheduled shipment of 1.2 million _____ of wheat from October, 1976, through January, 1977, under the long-term credit phase of the Food for Peace Program.
   j. A problem with high-lysine corn is that it produces a test weight of about 22.7 _____, rather than a more desirable level of 25.4 _____.

k. On a certain FFA plot of land it was estimated that 5 _____ of soil were lost to erosion each year for each 2 _____ of grain produced under conventional tillage.

l. The Agriculture Departmont reported that retail beef prices in July, 1976, averaged slightly more than $3.04 per _____, down from a record of $3.54 per _____ in July of 1975.

m. It takes nearly 2.2 _____ of steer on the hoof to make one _____ of beef for the supermarket.

n. The average _____ of fresh cattle manure contains about 5 kilograms of nitrogen.

o. Well-fed cheviot ewes that have raised lambs should shear at least 5 _____ for the year.

2. Estimate the mass of each of the following. Check your estimates by means of a balance or scale. Some objects you are near often; the masses of these you will want to remember.

Object	Estimated Mass	Measured Mass
Lug wrench		
Fence post		
Oil filter		
Grease gun		
Spark plug		
Hammer		
Textbook		
Glass		
Tool box		
Pencil		
Billfold		
Bag of seed		
Pruning shears		
_____		
_____		
_____		

3. Choose the best answer from those provided.

a. A cubic meter of corn has a mass of about _____.

(1) 600 mg (2) 600 kg (3) 600 g

b. The mass of a can of horse fly repellent is _____.

(1) 1 mg (2) 10 kg (3) 100 g

c. A roll of woven wire fence 10 lines high has a mass of _____.

(1) 127 kg (2) 7 mg (3) 12.7 kg

d. Wheel bearing grease may be sold in _____ containers.

(1) 500 mg (2) 50 kg (3) 0.5 kg

e. The mass of an apple seed is about _____.

(1) 1 g (2) 1 mg (3) 10 mg

Changing from one unit of mass to another in the metric system is easily done in the same way as with linear units. Knowledge of the meaning of each prefix is all that is required.

1 milligram = 0.001 gram 1 gram = 1000 milligrams

1 kilogram = 1000 grams 1 gram = 0.001 kilogram

4. Complete the following.

a. 750 g = _____ kg

b. 1450 g = _____ kg

c. 500 mg = _____ g

d. _____ g = 2.5 kg

e. 1450 kg = _____ g

f. _____ mg = 0.450 g

g. 10 g = _____ mg

5. A 25 kilogram bag of fertilizer is labeled 15-40-5. This means that of the ingredients in the bag, 15% is nitrogen, 40% is phosphate, and 5% is potash. How many kilograms of nitrogen, of phosphate, and of potash are there in this bag of fertilizer?

6. One liter of a certain concentrated liquid fertilizer has a mass of about 1.3 kilograms. What is the mass of a 10 liter container filled with this fertilizer?

7. How many kilograms of seed are needed to plant 70 hectares of soybeans if the beans are planted in rows at the rate of 50 kg/ha?

8. A dairy farmer transports an average of 140 kg of milk to market each day. About how many two-liter bottles can be filled with this milk? (Note: The mass of 1 L of milk is about 1 kg.)

Volume-Mass

One of the nice features built into the metric system is the relationship between volume and mass. For several reasons water has been used to establish this relationship: 1 dm^3 of cold water has a mass of 1 kg. (To be exact, the water should be distilled and at a temperature of 4 °Celsius.) Thus, 5 dm^3 of water has a mass of 5 kg. Furthermore, because the specific density of all other substances is related to water it is easy to find the mass of any substance if the volume of the substance is known. For example, the density of steel is 8 times that of water so 1 dm^3 of steel has a mass of 8 kg, 2 dm^3 of steel has a mass of 16 kg; alcohol is only 0.84 times as dense as water so 1 dm^3 of alcohol has a mass of 0.84 kg, 2 dm^3 of alcohol has a mass of 1.68 kg, etc.

Since 1 dm^3 = 1 liter, 1 liter of cold water has a mass of 1 kg as well. Also since 1 dm^3 = 1000 cm^3 = 1 liter, 0.001 dm^3 = 1 cm^3 = 1 milliliter. So 1 cm^3 of cold water has a mass of 1 gram and likewise 1 mL of cold water has a mass of 1 gram. For larger volumes, observe that 1 m^3 = 1000 dm^3. So the mass of 1 m^3 of cold water is 1000 kg or 1 metric ton.

Remember that this relationship is true for water—not other substances. However, 1 dm^3 of most liquids would have a mass of approximately 1 kg. In contrast, 1 dm^3 of corn has a mass of 0.72 kg and 1 dm^3 of oats has a mass of 0.41 kg.

Suggested Exercises

1. 6 mL of water has a mass of 6 _____.
2. 15 g of water would have a volume of _____ mL.
3. 250 g of water has a volume of _____.
4. _____ cm = 1 dm, so _____ cm^3 = 1 dm^3.
5. _____ dm = 1 m, so _____ dm^3 = 1 m^3.

6. 1 cm^3 of cold water has a _____ g mass.

7. 1 dm^3 of cold water has a mass of _____.

8. 1 m^3 of cold water has a mass of _____ kg = 1 metric ton.

9. The water in a tank 5 m by 4 m by 1.4 m has what mass?

10. In contrast to #9, try this one:

    The water in a tank 5 yd. by 4 yd. by 1.4 yd. weighs how much? (Hint: One cubic foot of water weighs about 62.5 pounds.)

It should be emphasized that the special volume-mass relationship in the metric system is restricted to volumes of cold water and their masses, not other substances. That is, a liter of cold water has a mass of 1 kg; a m^3 of cold water has a mass of 1000 kg; 1 milliliter of cold water has a mass of 1 gram.

To help with this understanding, the following experiment is suggested:

a. Take two containers, similarly constructed, each large enough to hold 1 liter.

b. Place the containers on opposite sides of a balance scale. Adjust the balance scale so that it balances properly. Fill one container with a liter of cold water and the other with a liter of popcorn. Are the scales now in balance? Does a liter of popcorn have a mass that is equal to, greater than, or less than a liter of cold water?

c. Repeat (b) above using a liter of sand or salt.

d. Repeat using a liter of buttermilk, molasses, vinegar, milk or some other liquid. In these cases are the masses approximately equal to that of a liter of water?

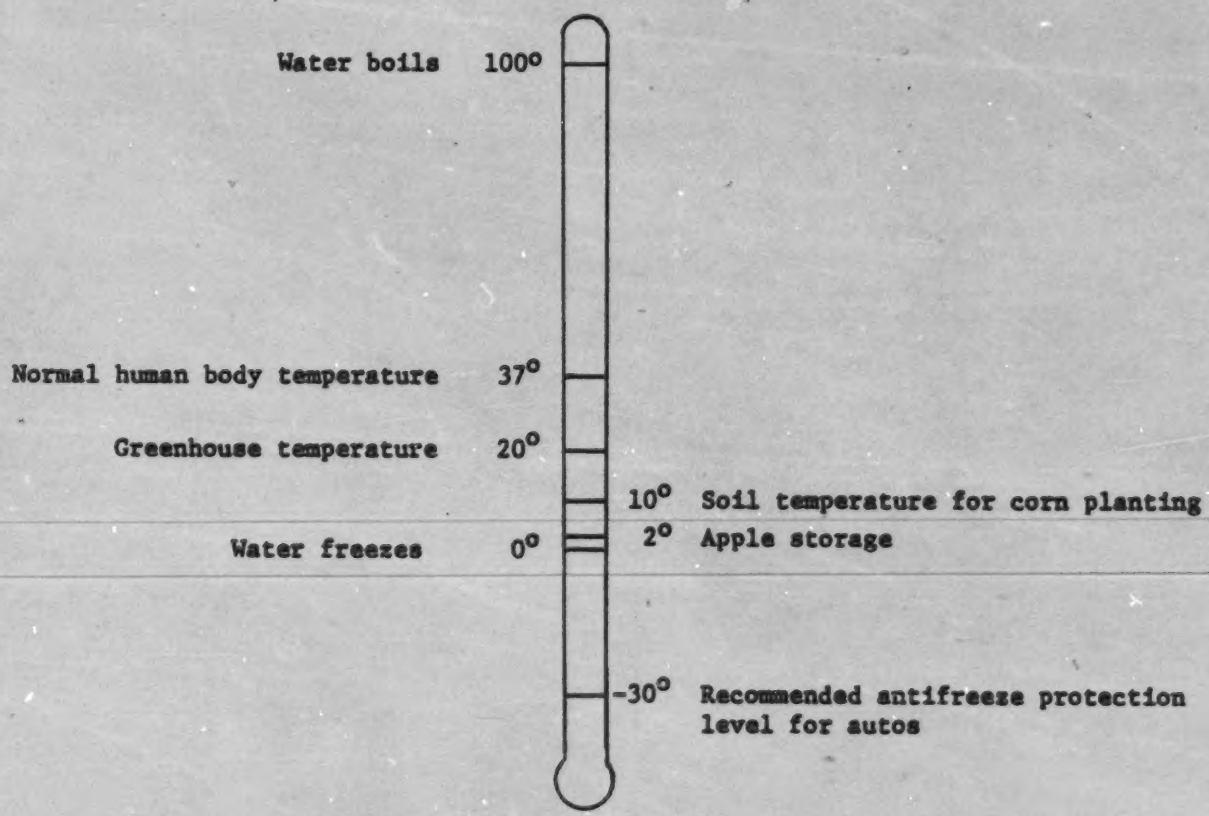
e. If the material is available, make a cube one decimeter on an edge out of cork or styrofoam. Compare the mass of this cube with that of a liter of water. (Caution: Be sure to compensate for the mass of the container holding the liter of water.)

Other Units

Several other units may be used to some extent in agricultural occupations. A few of these are discussed here.

Temperature

The basic SI unit of temperature, the kelvin, will be used primarily in the sciences. Temperatures for most non-scientific work will be reported in degrees Celsius (°C). This is not a basic SI unit but it has been accepted for use with SI. The Celsius scale is named after the first man to use it and is identical to the centigrade scale that has been in use for many years. (The term centigrade, which is also an inclination measurement of 0.01 of a right angle, should no longer be used for temperature measurements.) A few important Celsius temperatures are pictured below.


Water boils 100°
Normal human body temperature 37°
Greenhouse temperature 20°
10° Soil temperature for corn planting
Water freezes 0°
2° Apple storage
-30° Recommended antifreeze protection level for autos

The following are some examples of Celsius temperature readings:

1. Soil temperature should be about 10 °C during the first few days after planting no-tillage corn;
2. Studies indicate that a mulch of oat straw can reduce the soil temperature at a depth of 2.5 cm by as much as 4.2 °C;
3. Potato tubers stored at about 5 °C may be adversely affected by the cold temperature as the starch is converted to sugar more rapidly than the sugar can be utilized;
4. A certain sugar cane borer starts to multiply profusely when the temperature falls below 36 °C and the humidity rises above 70%.

Although generally discouraged, it may be helpful at times to make conversions between Celsius and Fahrenheit readings. An everyday approach is suggested. Get acquainted with several corresponding temperature readings in the two systems. For example:

0 °C = 32 °F

100 °C = 212 °F

20 °C = 68 °F.

Note that 20 °C or 68 °F is the furnace thermostat setting recommended by the federal government at the height of the energy crisis. These reference points, together with the fact that a change of 1.8 °F is equivalent to a change of 1 °C should be adequate for most purposes in making this change from one scale to the other. There are rules of thumb and formulas which can be used for making the conversions, but these are somewhat cumbersome and time consuming to use. Conversion scales are available commercially as well.

Force

The SI unit of force is the newton (N). One newton is the force needed to give a mass of 1 kg an acceleration of 1 meter per second per second. In symbols this is expressed as: force (N) = mass (kg) x acceleration (m/s^2),

$$1\ N = 1\ kg \cdot m/s^2.$$

The newton is used when measuring the force needed to stretch a rubber band, to depress an automobile accelerator, to drag a box across the floor, to lift a baby, and when measuring the force of gravity. More specifically, the force needed to lift an apple is about 1 newton. Capabilities of machines or tools may be listed in newtons, e.g., a 5000 N fence stretcher or a 10 000 N hoist.

In the past, scientific and other technical use has differentiated between weight and mass. At the present time, however, recommendations to the International Committee for Weights and Measures, and practices initiated by the American National Metric Council (ANMC) and the National Bureau of Standards (NBS) indicate that the term weight will be avoided in scientific and other technical fields. The term force of gravity will be used instead. In everyday activities the term weight may be used synonymously with mass.

The force of gravity on an object can be approximated if its mass is known. A kilogram mass exerts a downward force on the surface on which it rests. On earth the acceleration due to gravity is about 9.8 m/s^2, so the force exerted is 1 kg x 9.8 m/s^2 = 9.8 N. Roughly then, a 1 kg mass has a force of 10 N and the gravity force on a 250 gram hamburger is about 2.5 N.

Exercises

1. What is the gravity force on a 450 g carpenter's hammer?
2. What force is required to give a truck whose mass is 3500 kg an acceleration of 2 m/s^2?

Energy-Work

The metric unit of work, energy, and quantity of heat is the joule (J). Both work and energy are computed by multiplying force and distance. This product would be expressed in newton-meters (N·m). Torque is also the product of force and distance but is rotational rather than linear. To distinguish between the linear and rotational action of the force involved, the joule is used as the unit of work and the newton-meter is reserved as the unit of torque.

In the customary system there are several units of energy but those most commonly used are the calorie, the kilocalorie ("large" calorie), kilowatt hour, and British Thermal Unit (BTU). The calorie is used primarily as a measure of heat energy and the large calorie is used for food energy. In the metric system (SI), the joule or kilojoule will be used for all measures of energy. Since the joule is rather small, the kilojoule (kJ) and megajoule (MJ) are likely to be used.

Listed below are the energy values for average servings of several different foods.

Food	Food energy
Salted peanuts, 50 mL	736 J
Coleslaw, 120 mL	343 J
Orange sherbet, 120 mL	540 J
Donut, cake type	523 J

Examples of energy consumption are:

Refrigerator per day	18 MJ
Range per meal	5.4 MJ
Oven per hour	1.8 MJ
Toaster per slice	18 kJ
Iron per hour	3.6 MJ

Water heater per day	43.2	MJ
Color TV per hour	1.18	MJ
100 watt bulb per hour	360	kJ
Hair dryer per hour	1180	kJ

The energy usage of the items above is currently measured in kilowatt hours. The kilowatt hour is a measure of work which is accepted in the SI but its use should not be extended beyond the present uses. Instead the megajoule should be used. Note that 1 kwh = 3.6 MJ.

Energy sources are of frequent concern in welding where the term heat is usually used instead of energy. A few examples follow:

> 1000 joules of heat is generated in the spot welding of two sheets of 1 mm thick steel that requires a current of 10 000 amperes for 0.1 second.
>
> About 1380 J are required to heat and melt 1 g of steel.
>
> In an oxyacetylene torch with an orifice flow rate of 28 L/min., the total heat available would be 25 kJ/s. Only 8.8 kJ/s is available at the torch tip.
>
> When heating or melting a metal with a laser beam, the concept of energy absorbed per unit of volume is important. The energy absorbed can be written in dimensions of joules per cubic millimeter (J/mm^3).

Power

Many different units of measure are now used to measure power. Some of them are BTU/h, cal/m, erg/s, ft·lb/h, horsepower, and ton of refrigeration. In the SI, there is only one unit of power--the watt (W). The watt is used as the unit of mechanical, electrical, and thermal power. The output of all power-producing devices will be expressed in watts; electric motors, gasoline engines--even auto engines. Also the power input required to operate some devices will be expressed in watts. A few basic formulas show the relationships among the

newton, joule and watt:

Energy (J) = work done

= force (N) x distance (m)

1 J = 1 N·m

Power (W) = rate of doing work (J/s) = $\frac{\text{energy supplied}}{\text{time (s)}}$

1 W = 1 J/s = 1 N·m/s

In order to supply 540 joules of energy in 9 seconds, the power required is

$$\frac{540\ \text{J}}{9\ \text{s}} = 60\ \text{W}$$

For larger quantities of power, kilowatt (kW) and megawatt (MW) are used.

Exercises

1. An electric heater supplies heat energy of 8 megajoules over a one hour period. What power is required?
2. A medium duty portable electric drill will deliver how much power?
   (a) 300 W (b) 300 kW (c) 3 MW
3. A moderately priced rotary gas powered lawn mower has _____ of power.
   (a) 250 W (b) 1 kW (c) 2 MW

Pressure-Stress

The SI unit for pressure is the pascal. It is the force of one newton per square meter (N/m^2), a measure similar to the conventional pound per square inch (psi). The pascal is a rather small unit of pressure. Imagine that 100 mL of water was poured evenly on a surface of one square meter. The layer of water would be very thin—only about 0.1 mm. The force exerted, one pascal, is quite small. Consequently, the kilopascal (kPa) will be frequently used. Some common pressures are:

Atmosphere	101 kPa
City water	280 kPa
Auto tire	200 kPa
Ten-speed bike tire	400 kPa
Tractor tire	150-170 kPa
Auto hydraulic brake system	30 000 kPa (30 MPa)
Compressed air	700 kPa
Cattle sprayer and fogger pump	1375 kPa

Some units of pressure which will be discontinued are pounds per square inch, centimeters of water, inches of mercury, millimeters of mercury, and the bar.

1 psi	= 6.9 kPa
1 cm of water	= 98 Pa
1 in. Hg	= 3.4 kPa
1 mm Hg	= 133 Pa
1 bar	= 100 kPa
1 millibar	= 100 Pa

Torque

Torque is the rotational tendency caused by a force as it acts about a point. It is determined by the formula:

Torque = Force x Length of lever arm

In the metric system, force is measured in newtons and length is measured in meters so the metric unit of torque is the newton-meter; its symbol is N·m. The metric unit of energy or work, the joule, is defined in newton-meters also. By taking care to express work and energy in joules only and torque in newton-meters there will be no confusion.

Torque is involved when tightening a jar lid, turning a screw with a screwdriver or tightening a nut with a wrench. A torque of 3 N·m would be likely when using a screwdriver. Tightening spark plugs might require a torque of 40 N·m. Larger measures of torque can be expressed using the usual prefixes, e.g., kN·m. The engine of a large car might develop a torque of 0.5 kN·m.

Torque wrenches are available with several different scales, including some which are calibrated in kilogram-meters. Soon, only those calibrated in newton-meters should be used. Existing wrenches may be re-calibrated by taping on a new scale.

Exercises

1. A torque wrench with a handle of length 60 cm is pulled with a force of 600 N. How much torque is applied?
2. For tightening head bolts a torque of _____ N·m would be applied.
   (a) 10 (2) 130 (c) 40
3. The engine of a small car develops a torque of about _____ N·m.
   (a) 40 (b) 100 (c) 160

Miscellaneous Exercises

1. How many hectares are in a field whose dimensions are 300 m by 400 m?
2. A field 300 m by 500 m is to be enclosed with 3 strands of barbed wire fencing. How many meters of wire are needed? If each roll of fencing contains 400 m, how many rolls will be needed?
3. An application of 170 kg nitrogen per hectare is recommended for corn. How much nitrogen is needed for a field 500 m by 480 m?
4. Drilling soybeans solid requires a seeding rate of about 140 kg/ha. How many metric tons of beans are needed to sow a field 320 m by 400 m? At a rate of 7.3 L/ha, how much Amiben should be applied to this field?
5. For wheat, a count of 160 kernels per m^2 on the ground after harvesting means a loss of 50 kg/ha. A kernel count of $40/m^2$ would indicate a total loss of how many kg in a field 200 m by 250 m?
6. A certain interstate highway required a right-of-way of about 90 m.
   a. How many square meters of land were needed for each kilometer of highway?
   b. How many hectares of land were needed for a 320 km stretch of this highway?
7. On an automobile trip of 576 km, a traveler used 76 L of gas. The fuel consumption for this trip was _____ km/L.
8. A combine with a 8-row head is traveling at 10 km/hr. What is the mass of grain harvested in a 10-hour day, assuming 0.75 m rows, 3 m^3 of grain per hectare with a density of 0.9?

Other Information

1. In a brochure "1975 Field Crops Weed Control Guide," the Illinois Co-operative Extension Service describes a process for calibration of spray equipment. Three of the steps describe the computations needed for determining the nozzle flow rate.

Step 1. Select and determine an appropriate ground speed. Measure a distance of 176 feet under existing field conditions and determine the time in seconds to travel 176 feet.

$$\text{Speed (MPH)} = \frac{120}{\text{Time (seconds) to travel 176 feet}}$$

If it takes 24 seconds to travel 176 feet, your ground speed is $120 \div 24 = 5$ miles per hour.

Step 2. Determine the suggested sprayer application volume in gallons per acre (GPA) from the herbicide label or printed recommendations.

Step 3. Use the following formula to determine the nozzle flow rate required:

$$\text{GPM} = \frac{\text{GPA} \times \text{MPH} \times \text{W}}{5940}, \text{ where}$$

GPA = gallons per acre (Step 2)

GPM = gallons per minute of nozzle output

MPH = miles per hour (Step 1)

W = width (inches) of nozzle pattern

boom spraying: W = nozzle spacing

band spraying: W = band width

drop-nozzles: W = width sprayed per nozzle

Example: To broadcast apply 20 gallons per acre at a speed of 5 miles per hour with a nozzle spacing on the boom of 20 inches will require a

nozzle flow rate of 0.337 gallon per minute or 43 ounces per minute.

$$GPM = \frac{20 \times 5 \times 20}{5940} = 0.337$$

With the metric system the computational process could be:

Step 1. Select and determine an appropriate ground speed. Measure a distance of 100 meters under existing field conditions and determine the time in seconds to travel 100 meters.

$$\text{Speed (km/h)} = \frac{360}{\text{Time (seconds) to travel 100 meters}}$$

If it takes 36 seconds to travel 100 m, your ground speed is 360 ÷ 36 = 10 km/h.

Step 2. Determine the suggested sprayer application rate in liters per hectare (L/ha) from the herbicide label or printed recommendations.

Step 3. Use the following formula to determine the nozzle flow rate required:

$$mL/min = \frac{L/ha \times km/h \times w}{60}, \text{ where}$$

L/ha = liters per hectare (Step 2)

mL/min = milliliters per minute of nozzle output

km/h = kilometers per hour (Step 1)

w = width (centimeters) of nozzle pattern

Example: To broadcast apply 180 liters per hectare at a speed of 10 km/h with a nozzle spacing on the boom of 50 cm will require a nozzle flow rate of 1500 mL/min or 1.5 L/min.

$$mL/min = \frac{180 \times 10 \times 50}{60} = 1500$$

2. Andorra juniper will attain a height of 30–45 cm and a spread of 1.5–2.5 m.

3. If a shrub has a root ball 60 cm wide and 40 cm deep, it should have a hole 120 cm by 55 cm.

4. If one has no other trees to reforest around, hardwoods and pines should be spaced 1.5 m x 1.5 m.

5. The stomach of a horse holds 7.5–15 liters.

6. To estimate the mass of cattle and sheep:

   Measure the chest circumference or heart girth in decimeters.

   Measure the length of the body in decimeters from the point of the shoulder to the pin bones.

   $$\text{Mass in kilograms} = \frac{\text{heart girth} \times \text{heart girth} \times \text{length}}{10}.$$

Appendix A

The Supplementary Units

Unit	Quantity	SI Symbol
radian	plane angle	rad
steradian	solid angles	sr

The Derived Units with Special Names

Unit	Quantity	SI Symbol	Definition
newton	force	N	$m \cdot kg \cdot s^{-2}$
pascal	pressure	Pa	N/m^2
watt	power	W	J/s
joule	energy	J	N·m
coulomb	electric charge	C	A·s
farad	electric capacitance	F	C/V
henry	inductance	H	V·s/A
hertz	frequency	Hz	1/s or s^{-1}
lumen	luminous flux	lm	cd·sr
lux	illuminance	lx	lm/m^2
ohm	electrical resistance	Ω	V/A
siemens	conductance	S	A/V
tesla	magnetic flux density	T	Wb/m^2
volt	electric potential	V	W/A
weber	magnetic flux	Wb	V·s

The Derived Units without Special Names

Unit	Quantity	SI Symbol
square meter	area	m^2
cubic meter	volume	m^3
meter per second	linear velocity	m/s
radian per second	angular velocity	rad/s
meter per second squared	linear acceleration	m/s^2
radian per second squared	angular acceleration	rad/s^2
newton-meter	moment of force	N·m
kilogram per cubic meter	density	kg/m^3
joule per kelvin	entropy	J/K
watt per square meter	thermal flux density	W/m^2

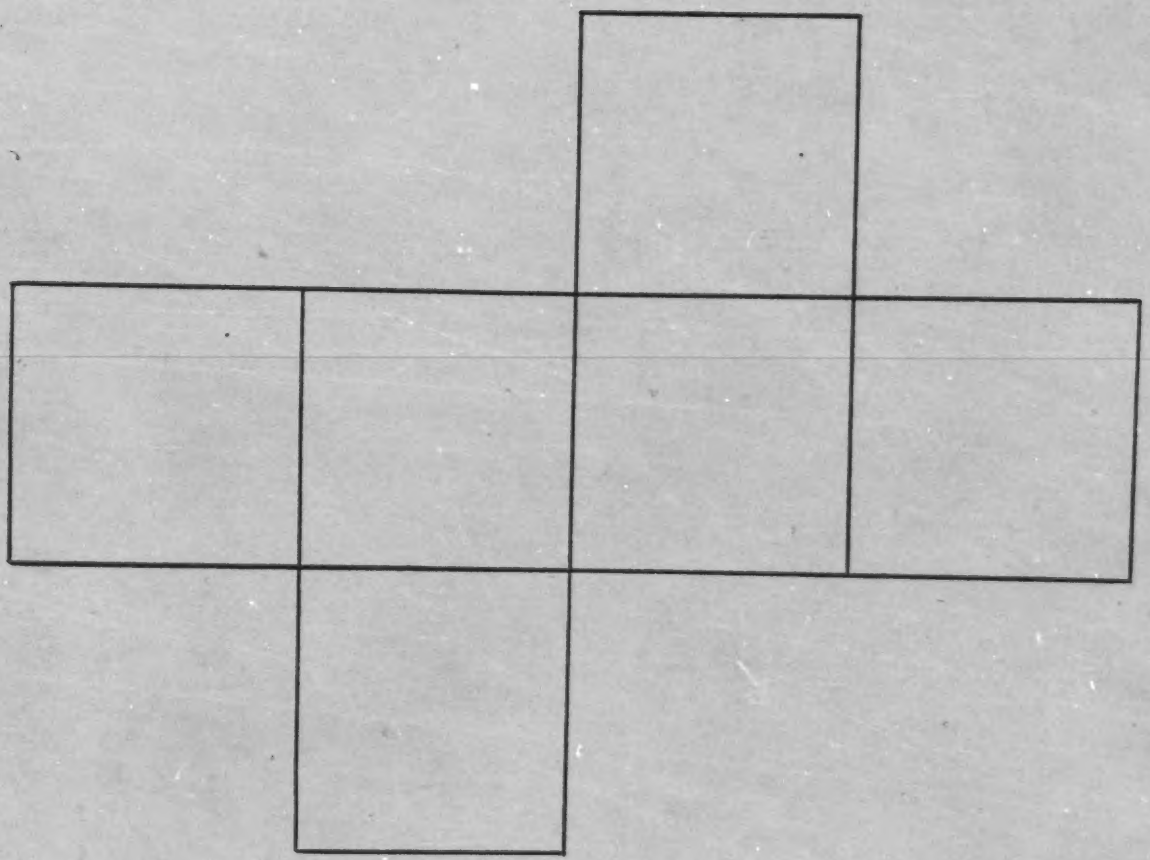
Prefixes

Names of multiples of SI and metric units are formed by using prefixes with "meter", "gram", "liter", "watt", or any other unit. Symbols use a prefix letter such as "ns" for nanosecond, "kHz" for kilohertz, "mV" for millivolt, etc.

giga	G	10^9	1 000 000 000	one billion
mega	M	10^6	1 000 000	one million
kilo	k	10^3	1 000	one thousand
hecto	h	10^2	100	one hundred
deka	da	10^1	10	ten
—	—	10^0	1	one
deci	d	10^{-1}	0.1	one tenth
centi	c	10^{-2}	0.01	one hundredth
milli	m	10^{-3}	0.001	one thousandth
micro	μ	10^{-6}	0.000 001	one millionth
nano	n	10^{-9}	0.000 000 001	one billionth
pico	p	10^{-12}	0.000 000 000 001	one trillionth

Appendix B

Suggested Diagram for Paper Cubes



Appendix C

Sources of Information

American National Standards Institute (ANSI), 1430 Broadway, New York, New York 10018.

Metric Editorial Guide, American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Guidelines for Writers of SI Metric Standards and Other Documents, Lou Perica, 1975, American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Guidance for Using the Metric System--SI Version, Valerie Antoine, Society of Technical Communication, 1010 Vermont Avenue, Washington, D.C. 20005.

Metric Practice Guide and Style Manual, National Bureau of Standards, AMJ Publishing Company, Tarzana, California 91356.

Metric Guide for Educational Materials, American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

The International (SI) Metric System and How It Works, Robert Hopkins, 1974, Polymetric Services, Tarzana, California 91356.

American Metric Journal. Published bimonthly by AMJ Publishing Company, P.O. Box 696, Tarzana, California 91356.

Metric Bulletin. Published monthly by J. J. Keller and Associates, Inc., 145 W. Wisconsin Avenue, Neenah, Wisconsin 54956.

Metric Reporter. Published biweekly by the American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Metric News. Published bimonthly by Metric News, Inc., 830 North 109th Street, Milwaukee, Wisconsin 53226.

A variety of Vocational-Technical Instructional Packages are available from the Center for Vocational Education, The Ohio State University, 1960 Kenny Road, Columbus, Ohio 43210.

Agricultural Occupations Sources

ASTM Standard for Metric Practice (ASTME 380-76), 1976, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

Metric Practice Guide for the Welding Industry, American Welding Society, 2501 N. W. 7th Street, Miami, Florida 33125.

John Deere SI Information, John Deere Product Engineering Center, P.O. Box 270, Waterloo, Iowa 50704.

Farming 74, Facts and Figures, Ed Jackson, editor, P.O. Box 4040, St. Paul, Minnesota 55116.

Farming 75, Energy Facts and Figures, 1999 Shepard Road, St. Paul, Minnesota 55116.

Welding Handbook, Vol. I, Fundamentals of Welding, American Welding Society, 2501 Northwest 7th Street, Miami, Florida 33125.

"Designing a Metric Gas Container," David W. Head, School Shop, January, 1975, pp. 29-30.

Appendix D

Standards Committees

ISO--The International Organization for Standards is an international, non-governmental agency for standards which is comprised of national standards bodies of about 80 nations.

ANSI--The American National Standards Institute is a federation of some 180 trade associations, technical societies, labor unions, and about 900 company members. ANSI is the U. S. member of ISO. ANSI does not write standards. It reviews and approves proposed standards written by committees administered by many technical and trade associations after all concerned groups have accepted them.

The address for ANSI is 1430 Broadway, New York, New York 10018. Current information about developments within specific trade associations is found in journals such as:

Metric News. Published bimonthly by Metric News, Inc., 830 North 109th Street, Milwaukee, Wisconsin 53226.

Metric Bulletin. Published monthly by J. J. Keller and Associates, Inc., 145 W. Wisconsin Avenue, Neenah, Wisconsin 54956.

Metric Reporter. Published biweekly by the American National Metric Council, 1625 Massachusetts Avenue, N.W., Washington, D.C. 20036.

American Metric Journal. Published bimonthly by AMJ Publishing Company, P.O. Box 696, Tarzana, California 91356.

Answers

Pages 15-17

4. a. m
   b. cm
   c. m
   d. mm
   e. dm
   f. cm
   g. cm; cm; cm; cm

5. a. 80 cm
   b. 15 dm
   c. 96 m
   d. 30 cm

6. a. 5600
   b. 5.6
   c. 3200
   d. 280
   e. 0.28
   f. 8
   g. 6.35; 635
   h. 5.8; 0.058
   i. 139
   j. $2\frac{17}{36}$; 89

7. 4200; 11 or 10.5

8. 399, 400, or 401 depending on where the planting begins and ends.

9. 7999, 8000, or 8001 depending on where the planting begins and ends.

10. a. 75
    b. 80
    c. 390
    d. 25 (24)
    e. 80
    f. 100
    g. 15 000; 0.15
    h. 55

Pages 19–25

3.

Region	Calculated Area	Region	Calculated Area
1	8 cm^2	4	9.6 cm^2
2	8 cm^2	5	12.6 cm^2
3	57 cm^2		

6. a. 3072 km^2
   b. 48 m^2
   c. 3 cm^2
   d. 22 m^2

7. a. 20 m^2
   b. 48 cm^2
   c. 28.8 m^2
   d. 209 m^2
   e. 175 000 m^2
   f. 88 920 m^2

8. a. 7400
   b. 600
   c. 1050
   d. 616
   e. 21
   f. 0.295
   g. 4.062 5
   h. 60

9. 4900; 9800
   a. 0.45
   b. 15
   c. 1
   d. 2

10. a. 30 000
    b. 0.5
    c. 500
    d. 2.5
    e. 4
    f. 500

11. a. km^2
    b. cm^2
    c. m^2
    d. cm^2
    e. m^2
    f. ha
    g. ha
    h. ha

12. 350

13. 3.6

14. 210

15. 270; 2.7

16. a. 32
    b. 10
    c. 75
    d. 200
    e. 640; 256

17. 6.25; 81

18. 50 000

Pages 27-28

3. a. dm^3
   b. cm^3
   c. m^3
   d. cm^3
   e. dm^3
   f. m^3

4. a. 2000
   b. 0.5
   c. 0.004
   d. 4
   e. 420
   f. 1491
   g. 102.4
   h. 0.186 321
   i. 144 000
   j. 0.144

5. 0.168

6. Yes

7. 0.283 160

8. 11.5

9. 137.984 ≐ 138

10. 5

11. 5000

Pages 31-33

2. a. mL
   b. L; L
   c. mL
   d. L
   e. L
   f. L

3. a. 4 L
   b. 8 L
   c. 2 mL
   d. 51 L

4. a. 1000
   b. 2
   c. 30
   d. 250
   e. 1
   f. 10 000
   g. 0.022
   h. 10

5. 500

6. 5

7. 500 000

8. 200

9. 20 000

10. a. 18
    b. 5
    c. 250
    d. 18
    e. 0.0015
    f. 300
    g. 70 cm^3; 70

11. 20 to 50 L

12. Yes

Pages 35-38

1. a. kg
   b. g
   c. g
   d. mg
   e. metric ton
   f. mg
   g. metric tons
   h. kg
   i. metric tons
   j. kg; kg
   k. kg; kg
   l. kg; kg
   m. kg; kg
   n. metric ton
   o. kg

3. a. 600 kg
   b. 100 g
   c. 127 kg
   d. 0.5 kg
   e. 10 mg

4. a. 0.75
   b. 1.45
   c. 0.5
   d. 2500
   e. 1 450 000
   f. 450
   g. 10 000

5. 3.75; 10; 1.25

6. 13 kg

7. 3500

8. 70

Pages 39–40

1. g

2. 15

3. 250 mL

4. 10; 1000

5. 10; 1000

6. 1

7. 1 kg

8. 1000

9. 28 metric tons

10. 23.625 tons

Page 43

1. 4.5 N

2. 7000 N

Page 46

1. 2.2 kW

2. 300 W

3. 250 W

Page 48

1. 360 N·m

2. 130

3. 160

Page 49

1. 12

2. 4800; 12

3. 4080 kg

4. 1792 kg; 93.44 L

5. 62.5

6. a. 90 000

   b. 2880

7. 7.6

8. 162 000 kg or 162 Mg